RANKING COMBINED UXO/CSM/HTW SITES REQUIRING RESTORATION: AN INITIAL PROTOCOL

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ABSTRACT

The need to develop a Hazard Ranking Scoring (HRS) methodology was created the discovery of buried mustard gas at the Raritan Arsenal, a Formerly Used Defense Site (FUDS) in New Jersey. The U.S. Army Chemical Materiel Destruction Agency (USACMDA) was formed to address the problem. One of its major objectives is to prioritize 200 potential sites that are possibly contaminated by Chemical Surety Materials (CSMs).

An in-depth site characterization is required to provide high quality input data for the ranking process. A detailed site history is of utmost importance to initially achieve the system's objective. This is particularly necessary for these sites because of the wide spectrum of hazards associated with CSMs.

A HRS protocol is presented in the context of investigation and restoration activities, that utilizes health risk concepts as the overall unifying mechanism. It is limited to one major activity, i.e., restoration of the soil medium at potential CSM sites. A distinction is made between safety hazards and health risks based on the basic philosophies of safety professionals and risk assessors. Included in the presentation is a customized and detailed analysis of the components of the major exposure pathway, a decision matrix to assist in classifying these sites, and a generalized and all-encompassing scoring procedure for prioritization. Conclusions are derived from this initial effort to provide some guidance for future endeavors in this field.

INTRODUCTION

The need to develop a ranking system was created by the discovery of mustard gas, a chemical surety material (CSM), during the restoration of the deactivated Raritan Arsenal in New Jersey. To further complicate matters the CSM was also found in adjacent areas, which had already reverted to public use. This event triggered a congressman's letter to the President (1). A program by the Department of Defense (DoD) to address the situation is rapidly developing in the newly formed U.S. Army Chemical Materiel Destruction Agency (USACMDA). It's mission is to oversee and operate the chemical demilitarization program. To accomplish that mission, USACMDA will develop overall programmatic plans and prioritize the effort to clean the estimated 200 formerly used defense sites (FUDS) that are suspected of chemical weapons (CW) material contamination (2). In addition to CSMs, the sites may also contain unexploded ordnance (UXO), and hazardous and toxic wastes (HTW) (2).

Prioritization needs are similar to those experienced by the U.S. Environmental Protection Agency (U.S. EPA) in startup of their regulatory programs authorized by the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) also known as "Superfund," and the Resource, Conservation and Recovery Act (RCRA). CERCLA had already developed a second generation Hazard Ranking System (HRS) for uncontrolled hazardous substances release as Appendix A of the statutes' regulations entitled the National Oil and Hazardous Substances Contingency Plan (NCP) (3). For the RCRA program, internal guidelines are used to systematically implement enforcement of this statute. This presentation uses the CERCLA HRS as a guide to a "first pass" effort at developing a ranking system for the Defense Environmental Restoration Program (DERP).

This paper considers a mixed materials site with CSMs, UXO, and HTW. A HRS protocol to address the ranking requirement is described in the following presentation, in the context of investigation and restoration activities. It utilizes health risk concepts as an overall unifying mechanism. It is not the objective of this presentation to provide a fully developed procedure for ranking the 200 sites, but to raise issues that must be addressed by any ranking

effort, and to present some possible development approaches. It is limited to one major activity, i.e., restoration of the soil medium at possible UXO/CSM/HTW sites.

An important distinction based on philosophies practiced by safety professionals and risk assessors is made between safety hazards and health risks. A risk assessor will presume that an unlikely events, e.g., detonation or violent chemical reaction with a subsequent fire will occur with some probability. The safety professional's goal is to reduce that probability to zero by implementing protective measures. Emphasis of this of this presentation is generally placed on health risk issues. However, it is recognized that the most critical elements of a hazard ranking system must address safety concerns. Therefore, it is presumed that safety hazards can be eliminated or controlled by the use of remote operating procedures, and specially constructed enclosures designed to contain releases of CSM in the event of a UXO detonation.

A detailed site history is of utmost importance for initially achieving the objective of any ranking system. The results of the ranking can be no better than the availability and accuracy of needed data that are qualitatively or quantitatively used as input to the system.

Behavior of the different classes of hazardous materials; i.e., UXO, CSM, and HTW, are very dependent on whether a detonation and/or violent reaction with subsequent fires occurs. The potential for a catastrophic event is totally dependent on: (a) containerization of the CSMs; (b) fuzing, arming and physical condition of UXO, and; (c) chemical nature of the major constituents related to violent chemical reactions and fires.

Barring detonations, violent chemical reactions and fires; environmental fate and transport of the toxic chemicals (all three categories are chemicals) may be the most significant aspect of the site. Migration potential is dependent on their chemical, biological and physical nature . Future use of the site will have a bearing on the level of effort needed to restore the site.

Potential receptors are defined as both onsite and offsite persons that could be exposed to hazards posed by the site. Their location as a potential exposure location, numbers, demographics and distribution will have decisive effect on public sensitivity and political viability.

The presentation is structured to detail the unique characteristics of a UXO/CSM/HTW site; comprehensively consider the components of an exposure pathway using risk assessment concepts; lists suggested scoring factors; and describes a "first-pass" hazard ranking system.

SITE CHARACTERIZATION

A listing of the elements of a site characterization in the context of a restoration activity, namely excavation and removal of soil contaminated with UXO, CSMs and HTWs is illustrated in Figure 1. There may be other aspects of the site that are specific to any one case. Consequently, it is not all inclusive. It is essentially equal to the level of effort used to characterize a CERCLA site, and is required in the RCRA permitting and corrective action programs.

Data generated by the site characterization effort are the basic input of the HRS. For the purposes of this presentation, the site characterization includes: (1) a site records review and survey by interviewing knowledgeable people to generate a history of the facility's activities from its inception to closure; (2) past investigation reports and future investigations containing information regarding the possible presence of CSMs, UXO, and HTWs that include waste characterization and chemical constituent identification; (3) physical, climatological and geological characterization of the site; (4) a potential receptor analysis; (5) future land use; and (6) regulatory history and an evaluation of the social-political factors defining public sensitivity to the site.

All of these components are presented in the context of potential exposure to hazardous and toxic materials from possible dispersion of CSMs from accidental detonation of UXO, violent chemical reactions and fires, and environmental transport of toxic constituents offsite.

The most important element of the site characterization is the site records review and survey since the possible entities may range from discarded CSM kits (most likely-with the CW agent dispersed to the environment 40 to 50 years ago) to buried containers (containing acutely toxic material) that are still intact.

The receptor analysis will provide insight into the public sensitivity of the location, and future land use will allow estimation of restoration costs and public pressures. The site setting, i.e., material attributes and extent of contamination are factors that assist in developing a restoration plan. Quality of the information generated from the site characterization will significantly affect the quality of the scoring of that particular site.

EXPOSURE PATHWAY COMPONENTS

Understanding of two simple risk assessment concepts are needed to follow the reasoning embedded in the procedure described in this paper: (a) there is no risk if either of two elements are missing, i.e., exposure and hazard; (b) a complete pathway is required for an exposure to occur. Figure 2 illustrates these concept in graphical form.

Elements included in an exposure pathway (in risk assessment terms) include: (1) a toxic agent (UXO, CSM or HTW); (2) a mechanism that releases the toxic constituent, i.e., detonation, violent chemical reaction, soil disturbance with release of particulates, mists or vapors, natural evaporation of a volatile constituent; (3) transport path through an environmental medium; and (4) a human and/or environmental receptor. Figure 3 shows the components of the exposure pathway and some aspects of each in specific aspects of a UXO/CSM/HTW situation.

Generally, the safety professional will try to reduce the risk to zero by making certain that a complete pathway is not present. Safety clothing, protective equipment, adherence to proven standard operating procedures, and performance of hazardous operations using remote methods are the tools of his trade. The risk assessor will postulate a complete pathway and attempt to quantitate a probability or qualitatively determine the potential for each of the exposure pathway components to exist at that particular site.

A combination of all three hazardous material classes present an extremely complex situation. This is due to: (1) the wide range of possible injuries and the toxicological extremes exhibited by the different material classes; (2) radically different levels of exposure contingent upon uncontrolled detonation, violent chemical reactions and/or fires; and (3) because most CSMs are not persistent in the environment, a dependency on extent and nature of the containerization.

Consequently, the release mechanism is a more critical factor in scoring a UXO/CSM/HTW site, and contrary to a Superfund site HRS evaluation where health risks associated with long-term exposure are the main concern. The potential for accidental release with rapid and extensive dispersion of the toxic constituents is the overwhelming concern for a combined UXO/CSM/HTW site.

The major transport pathway in this context is particulate dispersion to ambient air during soil excavation. Releases can be radically altered by a detonation or violent reaction from mixing of incompatible chemical constituents. The nature of the CSM may be such that concern for potable water sources may be a factor. Table 1 adapted from the United Nations report on the efficacy of chemical warfare (4) provides water solubility, volatility and hazard duration for various CSMs. It provides some comparative data that is useful for the evaluation of the migration-potential of these materials.

Proximity of human receptors is an important factor in characterizing the potential impacts of releases of hazardous constituents. The major exposure mode is inhalation of the dispersed air particulates, as dermal absorption may not be significant depending on the time frame (sufficient time for the UXO/CSM/HTW to break down to non-toxic constituents).

An understanding of the exposure pathway components and the critical factors that affect exposure is used to develop the decision matrix described in the next section.

SUGGESTED HAZARD RANKING SYSTEM FACTORS

As a first try at developing a HRS for UXO/CSM/HTW sites, it was immediately apparent that some sort of decision matrix would be required. This was necessitated by the complexity of the toxicity and exposure scenarios. Figure 4 shows an embryonic decision flow diagram with the various paths taken depending on many decisions reached during execution of the HRS.

An early recognition of the objective of the HRS is needed to perform a cost-effective evaluation. Main objectives of any HRS are to prioritize funding, rank sites by the level of hazard, address the sites by the level of public sensitivity, and finally by feasibility of restoration. The most likely basis for ranking will be the potential hazards and risks posed by the site.

However, if there is no distinct delineation between sites on this basis, funding may be a factor. An overriding factor may be institutional constraints. If restoration is totally constrained by socio-political concerns making it unfeasible, then a review of options may be required.

The initial scoring procedure entails selecting viable exposure pathways and evaluating those pathways using three parameters: (a) release potential; (b) toxicity/hazard characteristics; and (c) target receptors. These are the same aspects used to rank Superfund sites for the National Priority List (NPL). Various numerical scores are developed for each of the three aspects similar to the procedure described in the NCP (3). Relative weighting factors are applied to the numerical scores.

In addition, a fourth scoring parameter, labeled "institutional constraints" is applied. Its numerical value ranges from zero for a restoration that is totally constrained (the site cannot be restored due to regulatory or public concerns) to 100 if there are no constraints. All four scoring parameters (three weighted using CERCLA methods, and one with a weighting factor of 1) are multiplied. This product is then divided by a scaling factor to normalize to a top score of 100.

In this manner, sites can be ranked in accordance with the need for addressing the presence of the hazardous and toxic material. Figure 3 presents possible aspects that qualitatively characterize release potential, numerical hazard/toxicity parameters, and target receptor qualities that allow evaluation. The list is not all-inclusive.

ELEMENTS OF THE HAZARD RANKING SYSTEM

The proposed HRS is divided into the four major components: (1) likelihood of releases; (2) hazard characterization, which is further subdivided into safety and toxicity factors because they are radically different; (3) human and environmental receptors; and (4) institutional constraints. See Figures 4A to 4C for a graphical representation of these elements.

LIKELIHOOD OF RELEASE (LR)

There is some potential for release of air particulates, and/or vapors and mists during the excavation and removal of contaminated soil containing UXO/CSMs/HTWs. Important factors

affecting the nature and release of air particulates during excavation and removal (restoration) are:

- Containerization status of the various classes of materials:

  UXO: CSM contained in UXO, or another container in close proximity to UXO, UXO condition (fuzed, unfuzed/unarmed; fuzed/armed) and state of deterioration of container. other toxic materials.

  CSMs: In buried drums.

  HTWs: buried drums or other containers.

- Soil disturbance with wind mobilization, wind erosion
- Transport in ambient air dependent on wind and atmospheric stability.
- Particulate settling dependent on aerosol characteristics of the particles, wind, and atmospheric stability.
- Intensity of physical displacement during excavation.
- Chemical and physical properties affecting soil adsorption, biodegradation, leaching.
- Ability of any specially constructed containment design to contain an accidental release.

Release of vapors and mists during excavation and removal of affected soil and its contents are affected by:

- Containerization of volatile constituents in shells, drums.
- Enhanced emission due to soil disturbance, opening of soil pore vapors to ambient air.
- Diffusion and dispersion rate are dependent on wind and atmospheric stability.
- Environmental degradation processes in ambient air, e.g., photolysis.

- Chemical and physical properties of the hazardous/toxic constituents that affect: soil absorption, leaching.

From the above listing it is evident that migration-potential play an important role in the likelihood and criticality of the release. Volatility, particle size, persistence in soil, photolysis, ambient air mixing based on meteorology are some of the characteristics that determine the nature and extent of the release. As previously stated, the most dominant factor is the type and completeness of the containerization.

HAZARD (TOXICITY) CHARACTERIZATION (HTC)

As conceptualized in this "first-effort" HRS, hazards and toxicity are considered separately. Hazards are considered in the greater context and considered to be safety oriented. Toxicity is characterized in terms of acute and sub-chronic toxicity for the onsite restoration personnel and workers at a partially active installation.

Safety Hazards

With regard to safety issues, the type of release mechanism is the most critical item. Initiation of the UXO fuze on the UXO with subsequent detonation causing fires and possible violent chemical reactions, is the most dominant scoring factor for a UXO/CSM/HTW site. This aspect may overwhelm the scoring, just as large potentially exposed population located near a Superfund site dominate the NPL rankings. It may be more practical to include sites associated with containerized CSMs and suspect FUDS with UXO containing CSMs into a separate category. It is also possible that there are no sites of this type in the 200 FUDS being considered by USACMDA. Actual existence of the "worst case" postulation must be established.

Chief safety concerns include: injuries/fatalities due to fire and/or violent chemical reaction due to accidental detonation of a CSM-containing shell with rapid dispersion before warnings and/or evacuations can be effective. This is the worst-case situation. Products of combustion may be more or less toxic with the remote possibility that "imminently dangerous to life and health" (IDLH) conditions may arise. Fuze type and the specific characteristics of the

UXO is a consideration regarding hazards faced by restoration personnel. General safety hazards that are enhanced by site characteristics would also be considered in arriving at a HTC score.

Toxicity Considerations

Toxicity of the chemical constituents in all of the hazardous materials categories are considered in relation to onsite workers and the general public. For the onsite workers; acute and subchronic toxicity, and the pattern of contamination are a concern. Limited exposure is expected in the short-term time frame. Chronic toxicity and carcinogenicity are pertinent for the general public. Lifetime exposure at an offsite location where the toxic constituents may migrate is the major issue. Presence of sensitive populations has some influence on the scoring in this classification. There may be other aspects of the health hazards to consider. A intensive effort to develop a more detailed HRS after the sites have been characterized is needed to pinpoint other factors requiring consideration.

HUMAN AND ENVIRONMENTAL TARGET RECEPTORS

Target receptors are divided into the risk assessment categories of onsite and offsite groups. The onsite group includes restoration personnel, onsite workers, visitors and trespassers. Terrestrial and aquatic flora and fauna are also considered in the onsite context. This was the case for the restoration of the Weldon Spring Ordinance Site in Missouri because it had become a wildlife refuge after deactivation. Offsite receptors encompass the general population and offsite flora and fauna.

Aspects to consider within this context include spatial distribution of the offsite population into upwind and downwind categories to determine the most exposed individual (MEI); and to also characterize the population, i.e., the most sensitive segment (aged and children).

Terrestrial fauna and flora and the general ecology are considered in the development of TR scores.

INSTITUTIONAL CONSTRAINTS

Institutional constraints may preclude the restoration of a FUDS if public sensitivity is intense, regulatory compliance cannot be met, and socio-political issues make it totally unfeasible to proceed. However, this may be an extreme scenario. There are regulatory and political constraints on some restoration technologies. The furor regarding the siting of a CSM-incinerator near Louisville is an example of this situation. National security issues may override all constraints. However, this is also an extreme situation at the opposite end of the spectrum of restoration choices. Future use of the site may place a limit on the restoration choices available. All of these items will have a significant effect on the restoration costs.

PRELIMINARY CONCLUSIONS

Some preliminary conclusions can be drawn from initial development of a HRS for UXO/CSM/HTW sites. These are:

- It is essential to mount an in-depth effort to develop a site history that will maximize the goal of cost-effective allocation of restoration funds.
- Containerization character is the most dominant factor for determination of the hazardous (safety-related) character of the FUDS.
- The site characterization effort should be useful in implementing a preliminary prioritization of the FUDS sites.
- Minimization and elimination of safety hazards are the most critical objective of the HRS. Main attention should be on sites expected to present potential for catastrophic releases. Health protection, both short- and long-term are of secondary importance in the HRS scoring procedure.
- Institutional constraints may render any restoration effort as being unfeasible.
- Public sensitivity may overwhelm the scoring process, thus changing the ranking of some sites. These sites may require prompt restoration activities, regardless of their technical and scientific aspects.

- It is necessary to develop a decision-matrix that identifies major goals of the HRS, provides site-specific guidance for the structure of the scoring system, and addresses socio-political issues.

- Any HRS developed for UXO/CSM/HTW sites will be significantly different than the CERCLA Hazard Ranking Scoring.

The ideas and guidance generated by development of this initial HRS should be beneficial in starting an in-depth study that will result in a cost-effective, health-protective, and safe program that addresses the problem of UXO/CSM/HTW FUDS in the United States.

REFERENCES

1. Public letter from the Honorable Bernard J. Dwyer, Member of Congress to President George Bush dated January 29, 1992.

2. Personal communications of James P. Pastorick with personnel of the U.S. Army Chemical Material Destruction Agency, June-August, 1992.

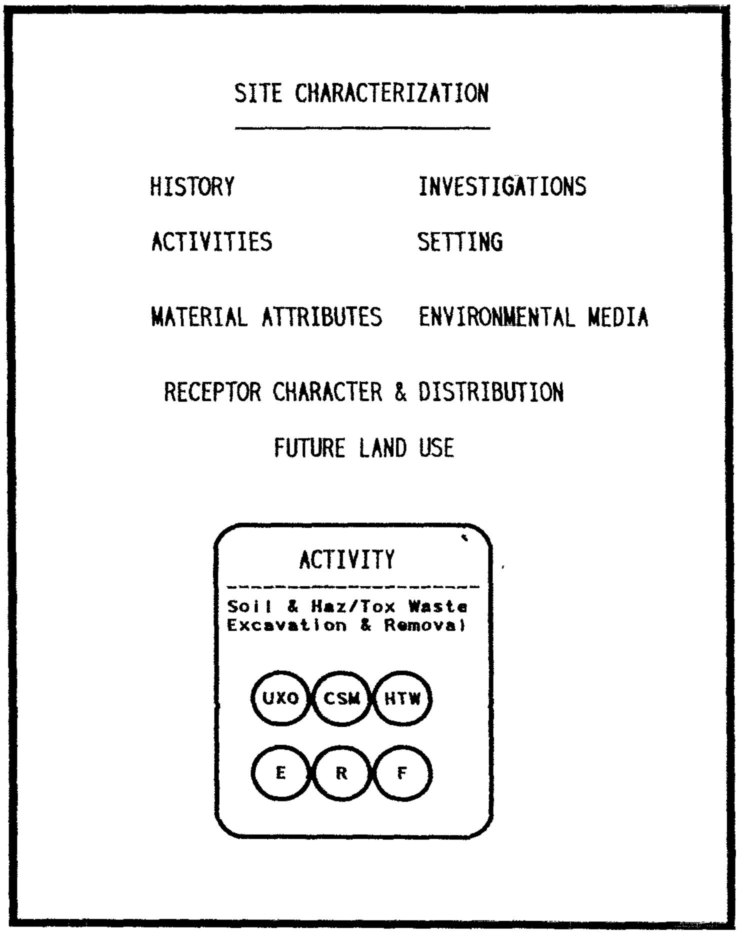
3. Federal Register dated December 23, 1988. Hazard Ranking System (HRS) For Uncontrolled Releases; Appendix A of the National Oil and Hazardous Substances Contingency Plan; Proposed Rule. Volume 53, page 51962.

4. Report of the Secretary-General of the United Nation titled "Chemical and Bacteriological (Biological) Weapons and the Effects of Their Possible Use." Department of Political and Security Council Affairs. New York: 1969.

TABLE 1. SOME PROPERTIES OF SELECTED CHEMICAL WARFARE AGENTS

1	Sarin	VX	Hydrogen cyanide	Cyanogen chloride	Phosgene	Mustard gas	Botulinal toxin A	BZ	CN	CS	DM
2	Lethal agent (nerve gas)	Lethal agent (nerve gas)	Lethal agent (blood gas)	Lethal agent (blood gas)	Lethal agent (lung irritant)	Lethal and incapacitating agent (vesicant)	Lethal agent	Incapacitating agent (psycho-chemical)	Harassing agent	Harassing agent	Harassing agent
3	Vapour, aerosol or spray	Aerosol or spray	Vapour	Vapour	Vapour	Spray	Aerosol or dust	Aerosol or dust	Aerosol or dust	Aerosol or dust	Aerosol or dust
4	All types of chemical weapon		Large bombs	Large bombs	Mortars, large bombs	All types of chemical weapon	Bomblets, spray-tank	Bomblets, spray-tank	All types of chemical weapon		
5	1 000 kg	1 000 kg	1 000 kg	1 000 kg	1 500 kg	1 500 kg	400 kg	500 kg	750 kg	750 kg	750 kg
6	100%	1-5%	100%	6-7%	Hydrolysed	0.05%	Soluble	?	Slightly soluble	Insoluble	Insoluble
7	12 100 mg/m^3	3-18 mg/m^3	873 000 mg/m^3	3 300 000 mg/m^3	6 370 000 mg/m^3	630 mg/m^3	Negligible	Negligible	105 mg/m^3	Negligible	0.02 mg/m^3
8 (*a*)	Liquid	Liquid	Liquid	Solid	Liquid	Solid	Solid	Solid	Solid	Solid	Solid
(*b*)	Liquid	Liquid	Liquid	Vapour	Vapour	Liquid	Solid	Solid	Solid	Solid	Solid
9 (*a*)	¼-1 h	1-12 h	Few minutes	Few minutes	Few minutes	12-48 h				—	
(*b*)	¼-4 h	3-21 days	Few minutes	Few minutes	Few minutes	2-7 days	—	—	—	2 weeks for CS1 ; longer for CS2	—
(*c*)	1-2 days	1-16 weeks	1-4 h	¼-4 h	¼-1 h	2-8 weeks				—	
10	> 5 mg-min/m^3	> 0.5 mg-min/m^3	> 2 000 mg-min/m^3	> 7 000 mg-min/m^3	> 1 600 mg-min/m^3	> 100 mg-min/m^3	0.001 mg (oral)	100 mg-min/m^3	5-15 mg/m^3 concentration	1-5 mg/m^3 concentration	2-5 mg/m^3 concentration
11	100 mg-min/m^3	10 mg-min/m^3	5 000 mg-min/m^3	11 000 mg-min/m^3	3 200 mg-min/m^3	1 500 mg-min/m^3	0.02 mg-min/m^3	?	10 000 mg-min/m^3	25 000-150 000 mg-min/m^3	15 000 mg-min/m^3
12	1 500 mg/man	6 mg/man	—	—	—	4 500 mg/man	—	—	—	—	—

KEY:
1. Common name
2. Military classification
3. Form in which the agent is most likely to be disseminated
4. Types of weapon suitable for disseminating the agent
5. Approximate maximum weight of agent that can be delivered effectively by a single light bomber (4-ton bomb load)
6. Approximate solubility in water at 20°C
7. Volatility at 20°C
8. Physical state (*a*) at —10°C
   (*b*) at 20°C
9. Approximate duration of hazard (contact, or airborne following evaporation) to be expected from ground contamination:
   (*a*) 10°C, rainy, moderate wind
   (*b*) 15°C, sunny, light breeze
   (*c*) —10°C, sunny, no wind, settled snow
10. Casualty-producing dosages (for militarily significant injuries or incapacitation)
11. Estimated human respiratory LC_{50} (for mild activity: breathing rate approx. 15 litres/min)
12. Estimated human lethal percutaneous dosages



HTW = HAZARDOUS & TOXIC WASTE
CSM = CHEMICAL SURETY MATERIALS
UXO = UNEXPLODED ORDNANCE

E = EXPLOSIONS
R = REACTION (CHEMICAL)
F = FIRES

FIGURE 1. ELEMENTS OF THE SITE CHARACTERIZATION

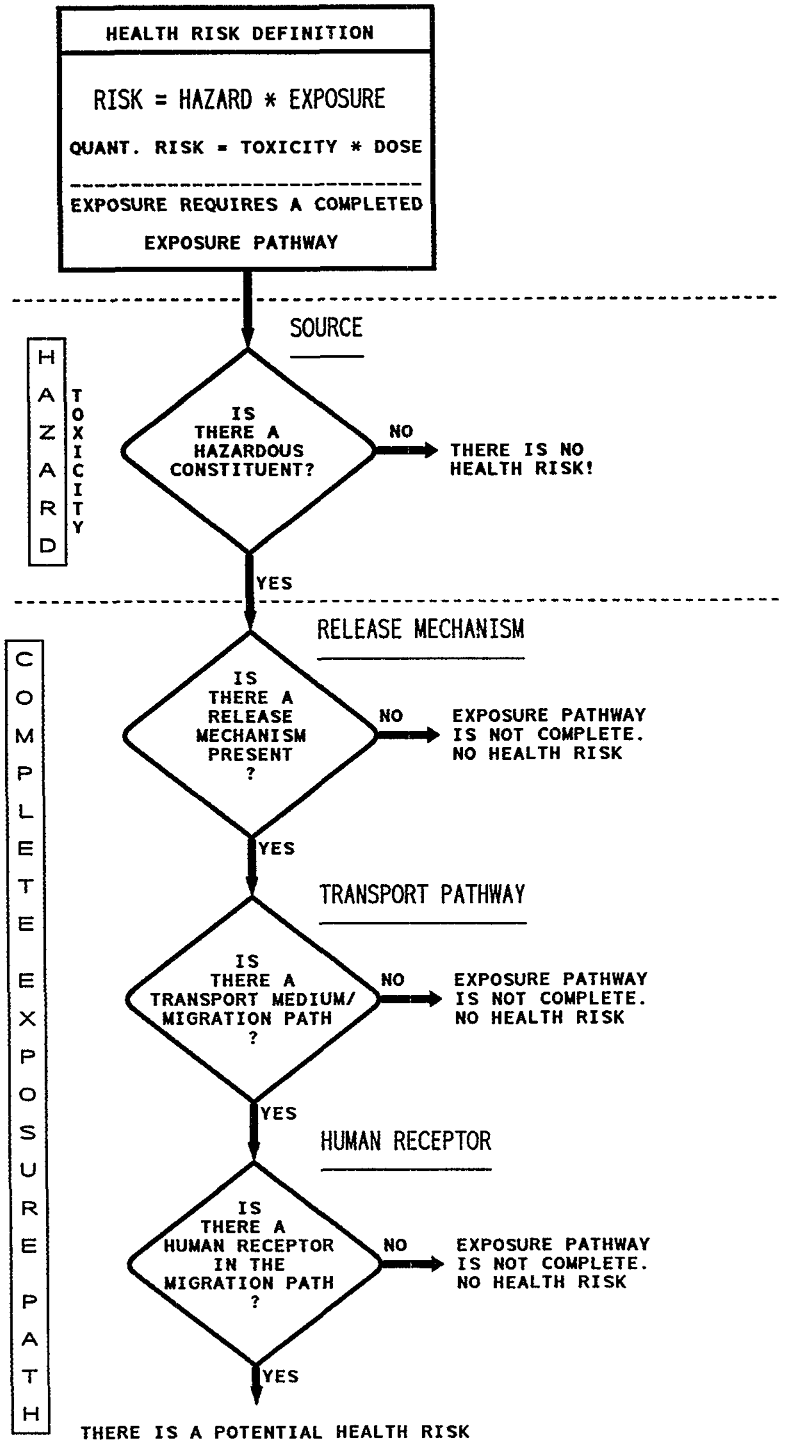


FIGURE 2. HEALTH RISK CONCEPTS ASSOCIATED WITH RISK ASSESSMENT

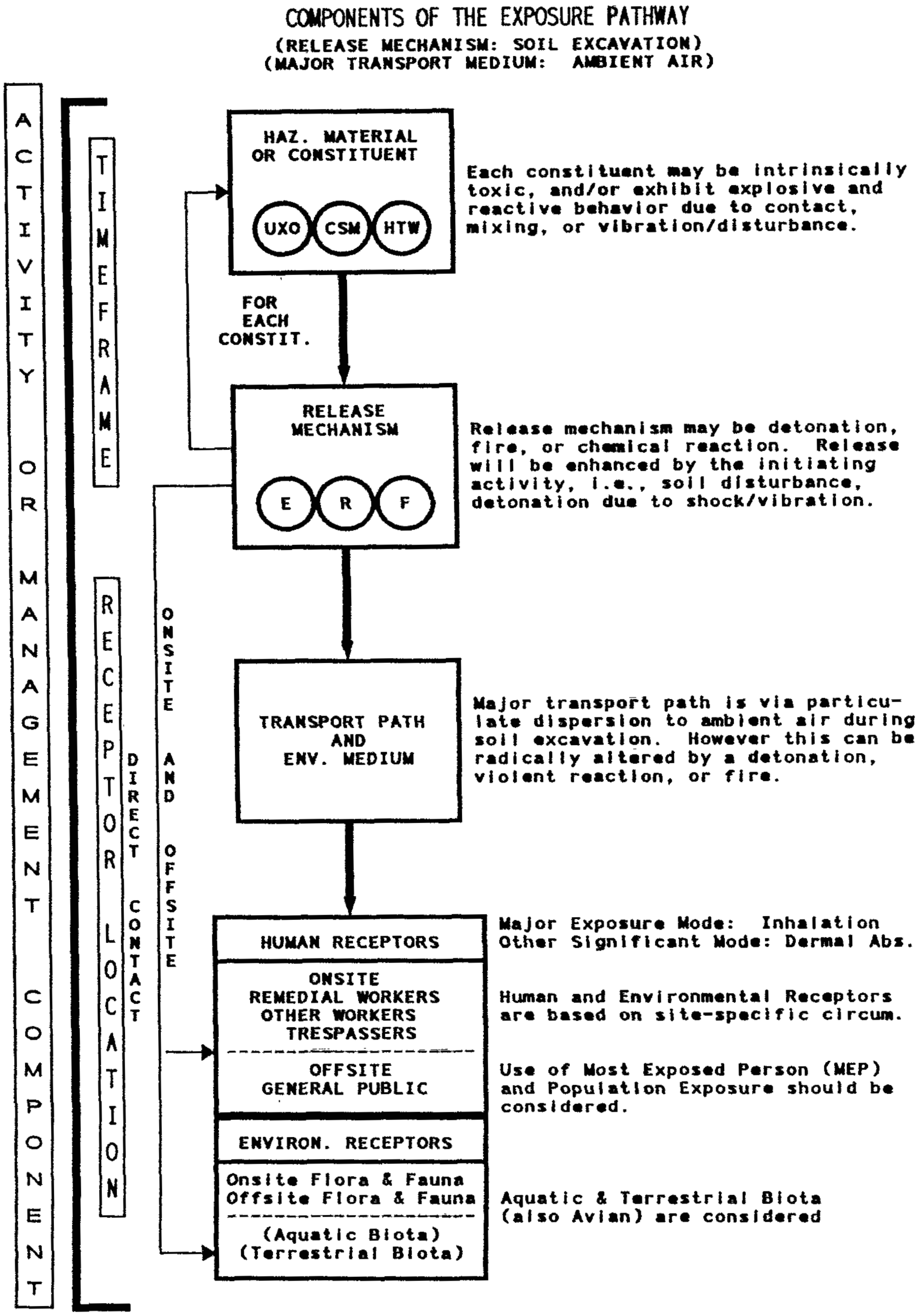
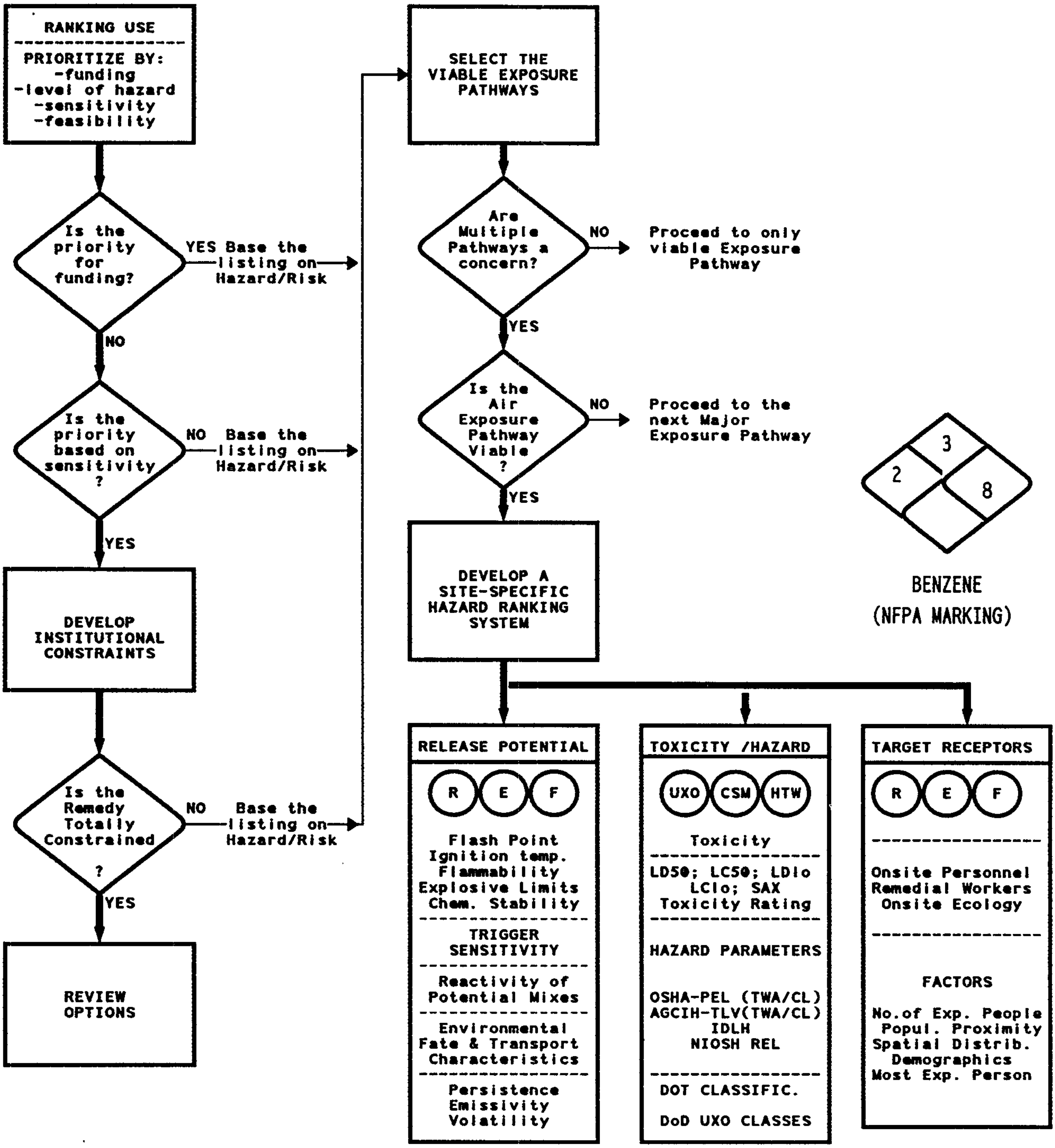


FIGURE 3. EXPOSURE PATHWAY COMPONENT FACTORS

SUGGESTED HAZARD RANKING SYSTEM FACTORS



SF = Scaling Factor (Normalize to 100)
IC = Institutional Constraint = 0 or 1

$$HRS = \left[\frac{[(W_1 * LR) * (W_2 * HTC) * (W_3 * TR)] * IC}{SF}\right]$$

FIGURE 4. HRS DECISION MATRIX FOR PROCEDURE DEVELOPMENT

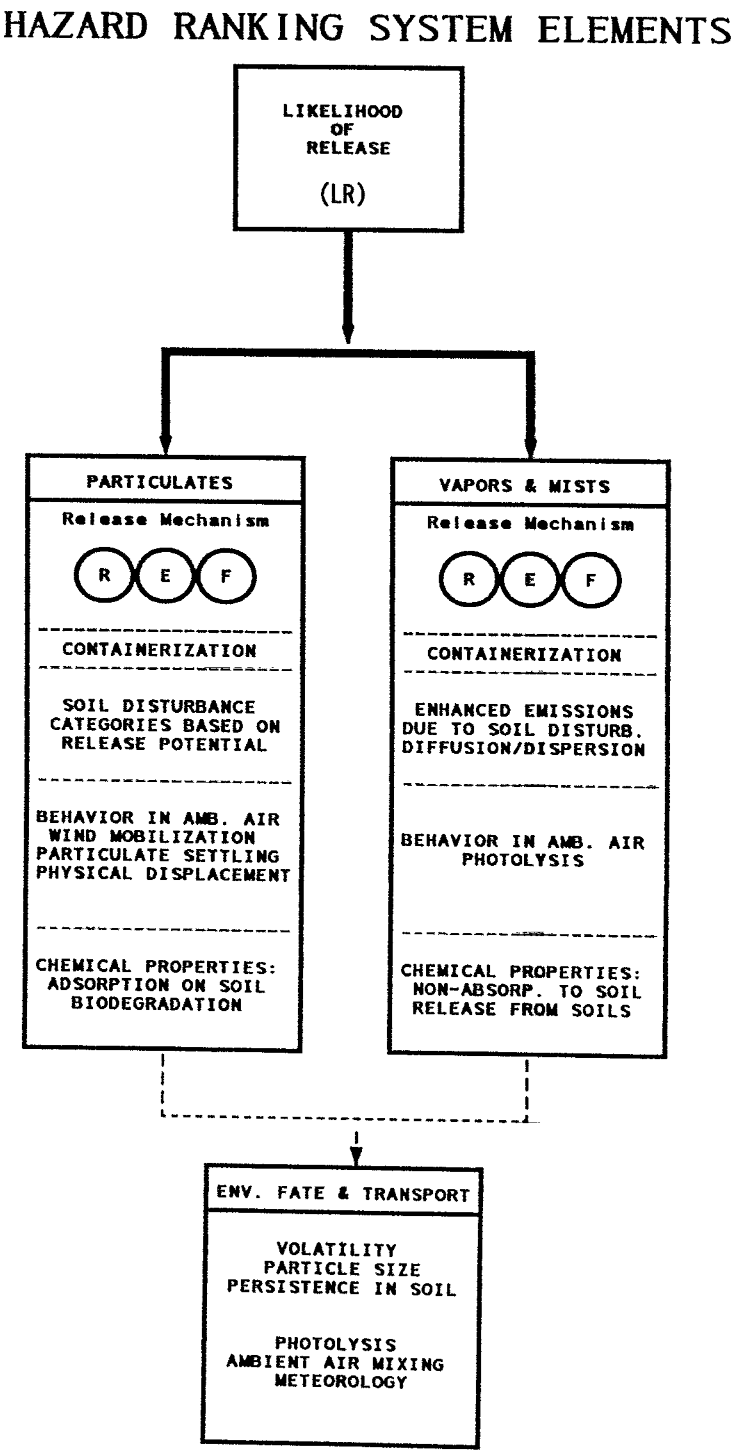


FIGURE 5A. HAZARD RANKING SYSTEM ELEMENTS

HAZARD RANKING SYSTEM ELEMENTS

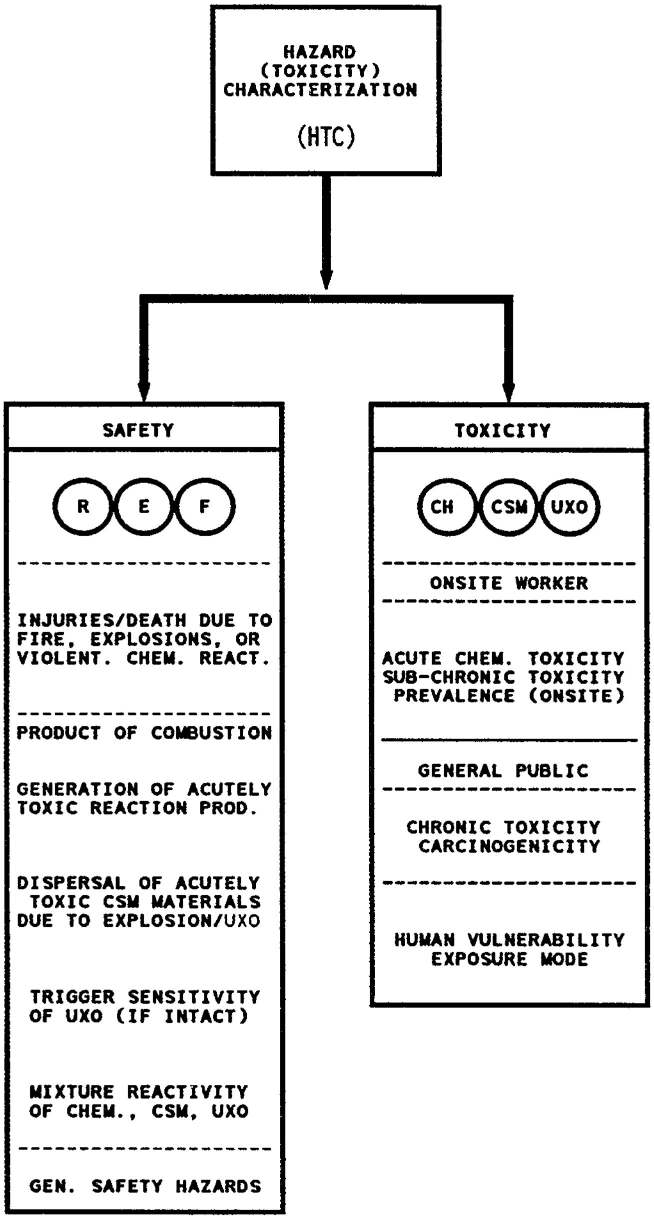
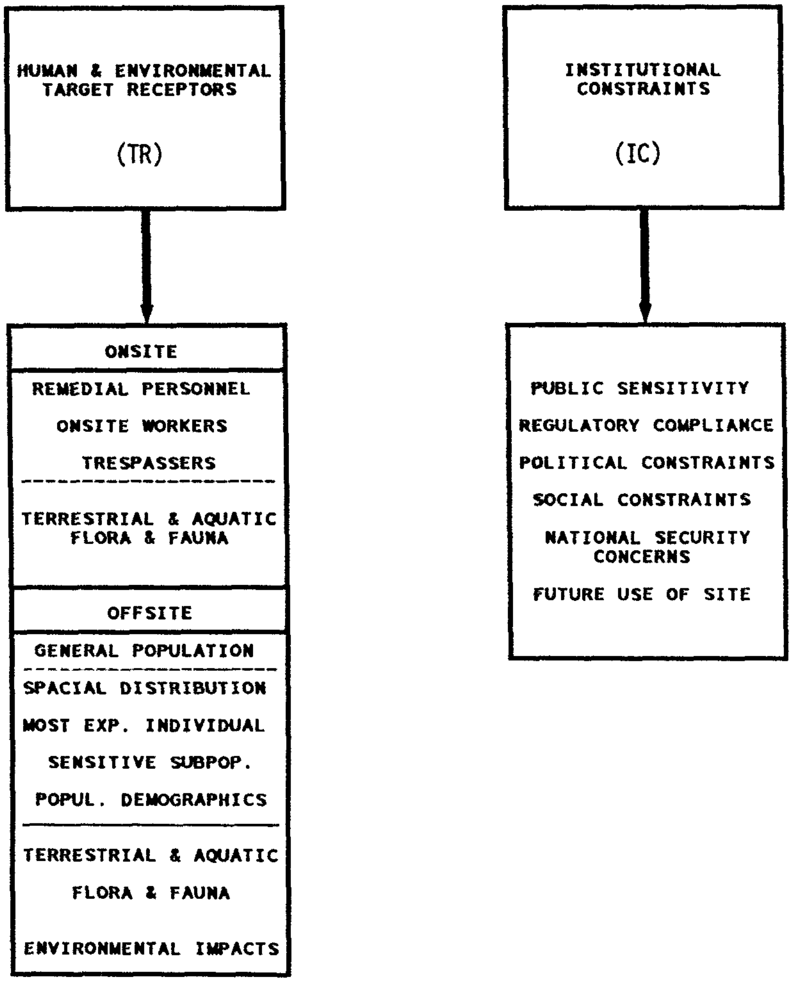


FIGURE 5B. HAZARD RANKING SYSTEM ELEMENTS

HAZARD RANKING SYSTEM ELEMENTS



$$HRS = \left[\frac{(W_1 * LR) * (W_2 * HTC) * (W_3 * TR) * (IC)}{(SF)} \right] IC$$

SF = SCALING FACTOR (To normalize to 100)
IC = INSTITUTIONAL CONSTRAINT = 0 OR 1

FIGURE 5C. HAZARD RANKING SYSTEM ELEMENTS